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SYSTEM AND METHOD FOR THREE-DIMENSIONAL SURFACE INSPECTION

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to the inspection of structures on an object and, more specifically, to a system and method for optically obtaining three-dimensional information regarding the position of structures on the surface of an object at high speeds.

Description of Related Art

Optical inspection devices typically hold an object to be inspected under an overhead camera, and illuminate the object from a single or multiple light sources. Typically, the optical inspection device lights the object from several directions in order to fully illuminate the surface and any objects thereon. The overhead camera captures a two-dimensional

gray-scale (black-and-white) image of the object and structures. In a process commonly called convolution, this image is then sent to a computer which compares the image, pixel by pixel, to a stored image of an object with properly positioned structures thereon. If any differences between the captured image and the image of the object with properly positioned structures are detected, the computer has detected a defective object. A typical application of this inspection technology is in the inspection of printed circuit boards (PCBs).

Sub C1 Other techniques for optical inspection such as the generation of structure grammar from captured images, tracing of structures to produce a set of primitives for the structure edges, the use of alignment techniques utilizing histograms to compensate for vibration and wobble of the support mechanism, and methods of automatic defect classification are disclosed in co-owned and co-pending U.S. patent application number 09/262,603 entitled *System and Method of Optically Inspecting Structures on an Object*, and co-owned and co-pending U.S. patent application number 09/338,880 entitled *System and Method of Optically Inspecting Surface Structures on an Object*, both of which are hereby incorporated by reference herein in their entireties.

Existing optical inspection systems and methods are becoming very efficient at obtaining and analyzing surface structures and defects which reveal themselves in the two dimensions of the surface of the object.

However, there is still a problem in rapidly and efficiently obtaining detailed and accurate information about the height of the structures. Some prior art systems have used lasers to obtain height information. When a laser is pointed at a particular point on the surface of the object, a small dot is formed by the laser beam. If the angle of incidence of the laser beam is less than 90 degrees, and there is a structure at this point, the dot is displaced horizontally from the position where the dot would be if there was no structure. The taller the structure, the greater the displacement. The vertically mounted camera can then detect the displacement of the laser dot, and height information can be computed from the magnitude of
in a process known as triangulation.
the displacement. However, this is a slow and inefficient process which is not suitable for obtaining height information over the entire surface of the object.

In order to overcome the disadvantage of existing solutions, it would be advantageous to have a system and method of rapidly and efficiently obtaining three-dimensional information regarding the position of structures on the surface of an object. The present invention provides such a system and method.

SUMMARY OF THE INVENTION

In one aspect, the present invention is an optical inspection system for inspecting at least one structure on a surface of an object. The system includes a first visual light source which illuminates the surface of the object and the structure with a light at a first visual frequency, and a first ~~laser~~ coherent light source which illuminates the surface of the object with a narrow coherent laser beam simultaneously with for example illumination by the first visual light source. The ~~laser~~ coherent light beam is emitted at a second visual frequency that is different from the first visual frequency of the visual light source. The first ~~laser~~ coherent light source is mounted off vertical on a movable mount which enables the ~~laser~~ coherent light beam to be directed over an area of interest on the surface of the object. The system also includes a color scan camera mounted vertically above the object. The camera has a first channel which captures an image of the illuminated surface of the object and the structure at the first visual frequency, and a second channel which captures a path of the ~~laser~~ coherent light beam as it strikes the surface of the object and the structure at the second visual frequency. A computer then determines two-dimensional structure information from the image at the first visual frequency, and determines height information for the structure from the path of the ~~laser~~ coherent light beam at the second visual frequency. The system may also include a second visual light source mounted on an opposite side of the object and illuminating the object at a third visual frequency.

Additionally, the system may include a second ~~laser~~ coherent light source oriented 90 degrees from the first ~~laser~~ coherent light source.

In another aspect, the present invention is a method of inspecting at least one structure on a surface of an object. The method includes the steps of illuminating the surface of the object and the structure with a first visual light at a first visual frequency, and simultaneously illuminating the surface of the object with a first narrow coherent laser beam at a second visual frequency that is different from the first visual frequency. The first laser beam strikes the surface of the object at an angle of incidence less than 90 degrees. The laser beam is directed in a path covering an area of interest on the surface of the object. This is followed by capturing an image of the illuminated surface of the object and the structure at the first visual frequency utilizing a first channel of a color scan camera mounted vertically above the object. Simultaneously, the path of the laser beam at the second visual frequency is captured utilizing a second channel of the color scan camera as the laser beam strikes the surface of the object and the structure. Two-dimensional structure information is then determined from the image at the first visual frequency, and height information for the structure is determined from the path of the laser beam at the second visual frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood and its numerous objects and advantages will become more apparent to those skilled in the art by reference to the following drawings, in conjunction with the accompanying specification, in which:

FIG. 1 is a simplified block diagram of a three-dimensional optical inspection system;

FIG. 2 is an illustrative drawing of a component mounted on the surface of a printed circuit board (PCB) illustrating the height-measurement technique of the present invention; and

FIG. 3 is a flow chart illustrating the steps of the method of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

The present invention advantageously combines several new inspection techniques in order to rapidly and efficiently obtain three-dimensional information regarding the position of structures on the surface of an object. The exemplary embodiment described herein is discussed in the context of a PCB inspection system. However, the system and method described herein may also be utilized to inspect other types of structures and objects.

FIG. 1 is a simplified block diagram of a three-dimensional optical inspection system 10. The present invention utilizes a coherent light source such as a laser light and multi-spectrum visual light together at the same time. A PCB 11 with components 12, or other formations such as solder blocks, on its surface is supported on a support mechanism 13. Two multi-spectrum visual lights 14 and 15 illuminate the PCB from opposite sides. Light 14 may be, for example green, while light 15 is blue. Two coherent red-light lasers 16 and 17 are mounted off the vertical (i.e., the angle of incidence of their laser beams is less than 90 degrees), and are mounted approximately 90 degrees apart horizontally. Thus, if laser 16 points at the PCB from the front, laser 17 may point at the PCB from the right side or the left side. The lasers are mounted on movable mounts 18 and 19, enabling the lasers to be pointed at any point on the PCB surface.

Ins C2 A color scan camera 20 is mounted above the PCB surface. The color scan camera performs a high speed scan of the PCB surface and utilizes red, green, and blue (RGB) channels to separate the signals of the laser light and the multi-spectrum visual lights.

The inspection system is under the control of a control computer 21. The control computer, or another dedicated computer, may also generate structure grammar from captured images, trace structures to produce sets of primitives for the structure edges, align multiple images utilizing histograms to compensate for vibration and wobble of the support

mechanism, perform height calculations, and perform automatic defect classification.

In operation, the green light 14 and the blue light 15 are used to illuminate the entire surface of the PCB. Simultaneously, the two coherent red-light lasers 16 and 17 are used to generate a series of parallel lines over the surface of the PCB 11. The lasers are mounted at 90 degree positions from each other and generate a grid of perpendicular red lines on the PCB surface. In addition, the lasers are strobed at a predetermined rate, so that both time-multiplexing and color-multiplexing can be used to separate the laser signal from the visual light signals generated by the green light and the blue light. The color scan camera utilizes its red, green, and blue channels to separate the red, green, and blue signals from the various light sources.

The color scan camera 20 is controlled to point at the same position as one or both of the lasers. Then the camera and the laser are scanned together over the surface of the PCB and take height readings across the PCB. By using the laser grid lines, the present invention can obtain height information over the entire surface of the PCB in a single high-speed scan. When a laser grid line encounters an object on the surface of the PCB, there is a discontinuity in the laser grid line. The magnitude of the discontinuity is measured in order to determine the height of the object.

The color scan camera takes a continuous series of exposures as it scans. By controlling the exposure time, the resolution of the height information in the direction of the laser line is controlled. A very short exposure time provides a height reading for a desired point on the surface. A rapid series of short exposures provides a height profile over a region of the surface. For longer exposure times, a series of height measurements may be integrated to provide an average height over the entire surface or a region thereof.

FIG. 2 is an illustrative drawing of a component 12 mounted on the surface of the PCB 11 illustrating the height-measurement technique of the present invention. Portions of two laser lines 31 and 32 are shown as they cross over the component 12. Dotted lines 33 and 34 illustrate the imaginary positions that lines 31 and 32 would present to the camera 20 if the structure was not present. Lines 31 and 32 are displaced from dotted lines 33 and 34 by distance "d". The displacement distance is dependent on the height of the structure and the angle by which the laser is mounted off the vertical. When the laser is mounted farther off the vertical, smaller height differences cause a greater displacement. Therefore, smaller height differences can be detected.

FIG. 3 is a flow chart illustrating the steps of the method of the present invention. At step 41, the PCB 11 to be inspected is positioned on the support mechanism 13. At step 42, the PCB is illuminated with blue

visual light, green visual light, and red laser light. At step 43, the color scan camera 20 is aligned with the position of one of the lasers 16 and 17. The color scan camera and the laser are then scanned together across the surface of the PCB at 44. The color scan camera uses its red, green, and blue channels to separate the signals from the three light sources. The red signal may be further differentiated, as noted above, by strobing the laser and using time-multiplexing to extract the signal. At 45, the signals from the green and blue channels are analyzed using known techniques to obtain two-dimensional information regarding the structure of the component mounted on the PCB. At 46, the signal from the red channel is analyzed using the techniques illustrated in FIG. 2 to obtain height information for the component. As noted above, this information may be utilized to determine a height profile, or the information may be integrated over a period of time at step 47 to obtain an average height value.

By utilizing the method of the present invention, the present invention can obtain three-dimensional structure information over the entire surface of the PCB in a single high-speed scan.

It is thus believed that the operation and construction of the present invention will be apparent from the foregoing description. While the system and method shown and described has been characterized as being preferred, it will be readily apparent that various changes and

modifications could be made therein without departing from the scope of the invention as defined in the following claims.